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CORONA satellite photography: an archaeological application from the Middle East

G. PHILIP, D. DONOGHUE, A. BECK & N. GALIATSATOS*

The declassification of CORONA high-resolution space photography has made a valuable new resource available for the study of ancient landscapes. Using a recent case-study from Syria, examples are given of various ways in which CORONA imagery can significantly enhance regional survey work.

Key-words: Satellite imagery; CORONA, archaeological survey, Syria, landscapes

Introduction

While the value of satellite imagery to archaeology is increasingly apparent, most current applications involve its use for environmental reconstruction (e.g. Oštir *et al.* 1999; Marcolongo & Barisano 2000). Because of the relatively low spatial resolution of the most familiar types of imagery (e.g. 30 m for Landsat multispectral data), these are of limited applicability for the identification of individual archaeological features (Kennedy 1998: 555). The resolution issue may explain the rarity of publications which document the systematic use of satellite imagery in the context of archaeological survey in the Mediterranean and Middle East (Sarris & Jones 2000: 53; Wilkinson 2000: 228).

Landsat Thematic Mapper imagery has been used to aid the identification of settlements and 'linear hollows' around sites in the Jazira of north Iraq (Wilkinson & Tucker 1995: 16–17, 25), and alongside SPOT panchromatic data (10-m resolution) to identify south Mesopotamian tell-sites and ancient irrigation canals previously known from air-photographs (Verhoeven & Dales 1994: 535). However, the effectiveness of satellite imagery alone for the identification of archaeological features remains uncertain because the latter report, while referring to sites as small as 1 ha in area (Verhoeven & Dales 1994: 537–9, figures 11, 13), does not make it clear by which of these means the smaller sites were, in fact, identified.

However, the declassification of military satellite photography in recent years, in par-

ticular Russian KVR 1000 and American CORONA imagery¹ offers researchers the ability to identify linear structures such as walls, tracks, and individual features measuring no more than a few metres in diameter; see Comfort *et al.* (2000: 103–6, 122–3, figures 3–5) for a brief comparison of the two types of data. As Kennedy (1998) has pointed out, such imagery is of great potential value for archaeology in parts of the world for which detailed maps and good air-photographic data have traditionally been hard to obtain. The discussion below documents one such case.

Settlement and Landscape Development in the Homs Region, Syria (SHR) is a joint Syrian-British co-operative project organized by the University of Durham and the Directorate General of Antiquities and Museums (DGAM), Syria (FIGURE 1). It is a multidisciplinary regional project designed to take a long-term perspec-

1 CORONA and KVR 1000 data have been acquired at a variety of ground resolutions and although these can be scanned, draped over a map backdrop and subsequently projected at various scales using GIS software, it is difficult to attribute a *map scale* in the normal sense of the term to the imagery itself. This issue has been touched upon by Petrie (1999: 2–3, table 2), in his discussion of the photographic scale of the negatives produced by various space cameras, but cannot be considered in detail in the present article. Suffice it to say for now that it is hard to make a direct comparison between photographic scale and images that are viewed in a digital format, because the process of digital scanning imposes a pixel resolution different from the process of photographic enlargement from a negative.

* Philip & Beck, Department of Archaeology, University of Durham, South Road, Durham DH1 3LE, England. Donoghue & Galiatsatos, Department of Geography, University of Durham, South Road, Durham DH1 3LE, England.

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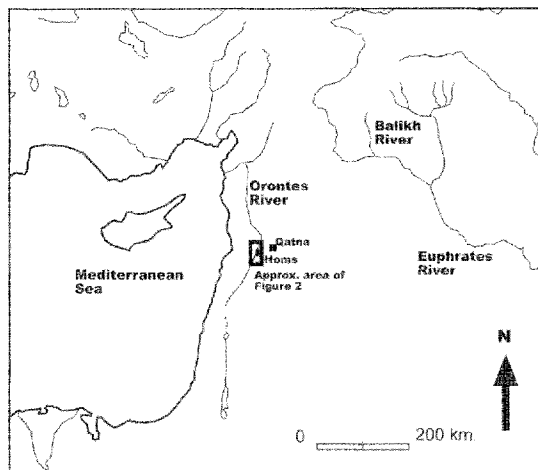


FIGURE 1. The east Mediterranean showing location of Homs.

tive on the relationship between human activity and landscape development in the upper Orontes Valley (Philip *et al.* in press). As such, the effective identification of hitherto undocumented loci of past human activity is of prime importance.

The project comprises a northern and a southern study area, with a combined area of approximately 600 sq. km² (FIGURE 2). Traditional subsistence strategies in this area have been dominated by rain-fed cereal cultivation, supplemented by tree crops. Preliminary assessment in 1998 indicated the presence of typical near-eastern tell sites, most of which appear on the current Syrian 1:50,000 maps, but also numerous low mounds and flat sites indicated by surface artefact scatters. A marked proportion of the latter do not appear on the maps, suggesting that they are significantly underrepresented within the current information base. As there had been little previous archaeological survey work in the area west of Homs, and neither aerial-photography nor topographic mapping at scales greater than 1:50000 were then available,² SHR required a means of focusing field investigation, and thus increas-

ing the rate at which an overall impression of the quantity, nature and distribution of archaeological remains could be obtained. A potential solution appeared to lie in the recently declassified CORONA imagery.

CORONA

The CORONA project operated from 1960 to 1972 during which time a series of satellites collected photographic intelligence for the United States military. The declassified data, which was placed in the public domain in 1996, includes extensive coverage of the Middle East. In this report we have used images taken by the CORONA camera system KH-4B, which provided imagery with ground resolution ranging between 2 m and 8 m. Details of the various CORONA satellites and technical characteristics of the data are discussed elsewhere (Donoghue 2001; McDonald 1995; 1997). The age of the data offers a particular advantage in that it records a late 1960s landscape. Not only does this reveal far less 'urban-industrial clutter' than that of the present day (Wilkinson 2000: 228), it also preserves landscape features which have been masked or damaged by changes in agricultural practices over the last three decades.

Methodology

CORONA data is not supplied in digital form, but as photographic products. These data are available from the United States Geological Survey Global Land Information System (USGS GLIS). The data are inexpensive, easy to obtain and relatively well documented, and the database of available images can be searched by geographic co-ordinates and scenes inspected over the web ('quick looks') at the USGS website (<http://edc.usgs.gov/Webglis/glisbin/search.pl?DISP>).

For our study the data were obtained as copy photographic negatives. While CORONA negatives can produce high-quality printed enlargements, there can be significant geometric distortion in the resulting images (Goossens *et al.* forthcoming). The utility of the data as far as landscape work is concerned is enhanced by its conversion to digital form, which allows its use within a Geographic Information System. This is achieved by scanning the selected area of interest from the negatives. As the resolving power of the film employed in CORONA missions was as high as 160 lp/mm (McDonald

2 We have recently learned from Dr Ma'amoun Abdelkarim of the University of Damascus of the existence of some French air-photographs of the Homs region dating to the 1930s. In addition Dr Levon Nordiguian of the Université de St-Joseph in Beirut has informed us that the collection of pre-World War II air-photographs taken by Poidebard also includes material covering the Homs area.

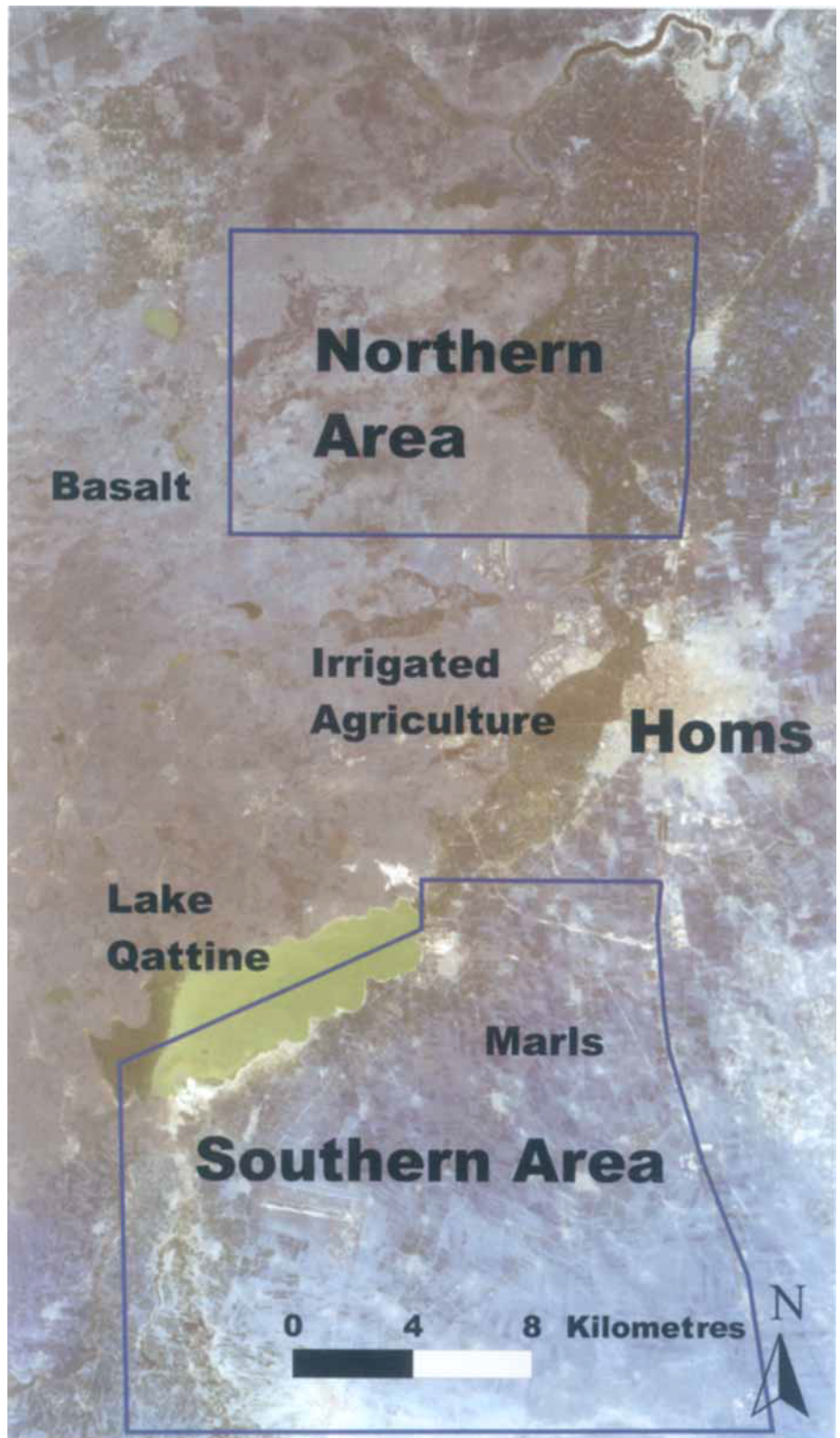


FIGURE 2. The Orontes Valley and surrounding areas showing northern and southern study areas; Landsat TM image ID: LT5174036008727410, 1 October 1987, Bands 3, 2, 1.

1997), high-resolution scanning is required to avoid loss of detail from the original image.³ In this case, the negatives were scanned with an optical resolution of 7.5 µm (equivalent to around 3400 dpi). For this, a photogrammetric scanner was employed as these produce digital files which are geometrically corrected to eliminate the known error of that particular machine. The result is a raster image (a tif file) which is subsequently geometrically corrected, with reference to either local topographic maps, or to GPS data collected in the field.

In digital form, CORONA data can be enhanced using image processing software, and incorporated as a layer within a GIS. This al-

lows a direct interface between the imagery and data derived from cartographic sources or collected in the field. This procedure also facilitates the comparison of individual features as they appear in different CORONA scenes, which will generally cover a range of seasons, times of day, and atmospheric conditions (Donoghue *et al.* 2002: 216-18).

CORONA as an aid to site detection

The value of CORONA imagery as an aid to site identification is best outlined with reference to a specific example area, which includes sites of several different types (TABLE 1, FIGURE 3). Those sites discussed below are located around 12 km south-southwest of Homs, in an area dominated by marls and conglomerates (Ponikarov *et al.* 1964). The image was taken after the harvest and so crop cover is minimal.

The two tell sites (SHR 255 and 256) were clearly marked on the 1:50,000 map series and both are readily visible on CORONA as distinct dark areas. The map-contours that indicate the tell of SHR 256 cover an area considerably smaller than the dark area visible on CORONA

³ The resolving power of a photographic emulsion refers to the number of alternating bars and spaces of equal width that can be recorded as visually separate elements in the space of one millimetre on the emulsion. The combination of a bar and a space is referred to as a 'line' or 'line-pair' and resolving power is specified in lines/mm (l/mm) or line-pairs/mm (lp/mm). Thus the figure 160 lp/mm provides an indication of the ability of the emulsion to provide distinct images of small, closely spaced objects (American National Standard Method for determining the resolving power of photographic materials, PH2.33-1969).

SHR no.	approx. size (ha)	periods identified	indication on 1:50,000 map	method of initial location
255	tell 0.7 ha, height 5 m	Bronze–Iron Age	name Tell Aqarib and contour	mapping
256	tell c. 2 ha, height 10 m	Bronze–Iron Age	name Tell Ahmad and contour	mapping
308	scatter of sherd/tile 1.5 ha, flat	Islamic	place-name Khirbat al-Matr, appears without symbol or contour indications	CORONA, confirmed by field-walking
446	olive press	Roman–Islamic	none	field-walking
447	sparse artefact scatter, extent uncertain	prehistoric	none	field-walking
454	scatter of sherd/tile 1.2 ha, flat	Roman–Byzantine	none	CORONA, confirmed by field-walking
458	scatter of sherd/tile, extent masked by recent tree planting	Roman/Islamic	none	CORONA, confirmed by field-walking
472	scatter of basalt fragments and flint; diameter 30 m	prehistoric? pastoralist campsite?	none	field-walking

TABLE 1. *Characteristics of sites in example area.*

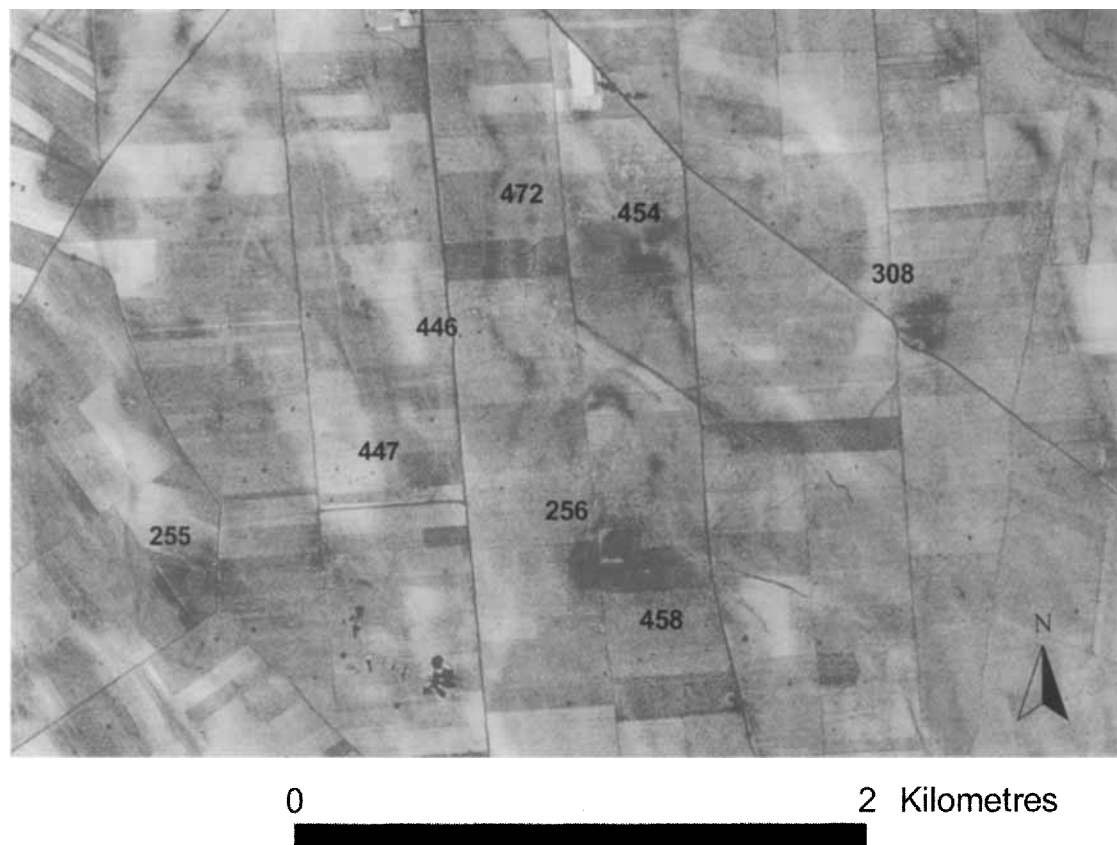


FIGURE 3. Visibility of archaeological sites in the marls of the southern study area, post-harvest landscape. CORONA Mission no. 1111, 31 July 1970.

which suggests that this might be a complex site. Field-walking confirmed that this was indeed the case as it revealed the presence of a distinct concentration of artefactual material (SHR 458) extending southwards from the south-eastern margin of the tell. This occupation was chronologically distinct from that on the tell itself. CORONA also proved highly effective in locating flat, but relatively extensive artefact scatters, a site category the importance of which had been highlighted by preliminary work in 1998, and which is underrepresented on the maps. SHR 308 and SHR 454 which appear as distinct dark zones are good examples. SHR 308 could be equated with a place name (*khirbah* — ruin) appearing on the 1:50,000 map, but in a location several hundred metres distant from the actual site (see TABLE 1). As expected CORONA was less effective in the identification of small, or sparse, artefact scatters, such as

447, several of which were located during field-walking.

It is not yet clear what is actually causing the relatively high visibility of ploughed-out settlements in CORONA images of this area. However, the most likely explanation is that certain characteristics of composition or structure result in a distinction between the reflectivity of soils containing quantities of anthropogenic debris, and those originating in the local geology. This problem is currently under investigation.

CORONA as a tool for mapping archaeological features

The basaltic landscape west of the Orontes River is characterized by extensive areas of rectilinear walls that demarcate ancient field systems. While these lie beyond the resolution of Landsat Thematic Mapper imagery, they are readily vis-

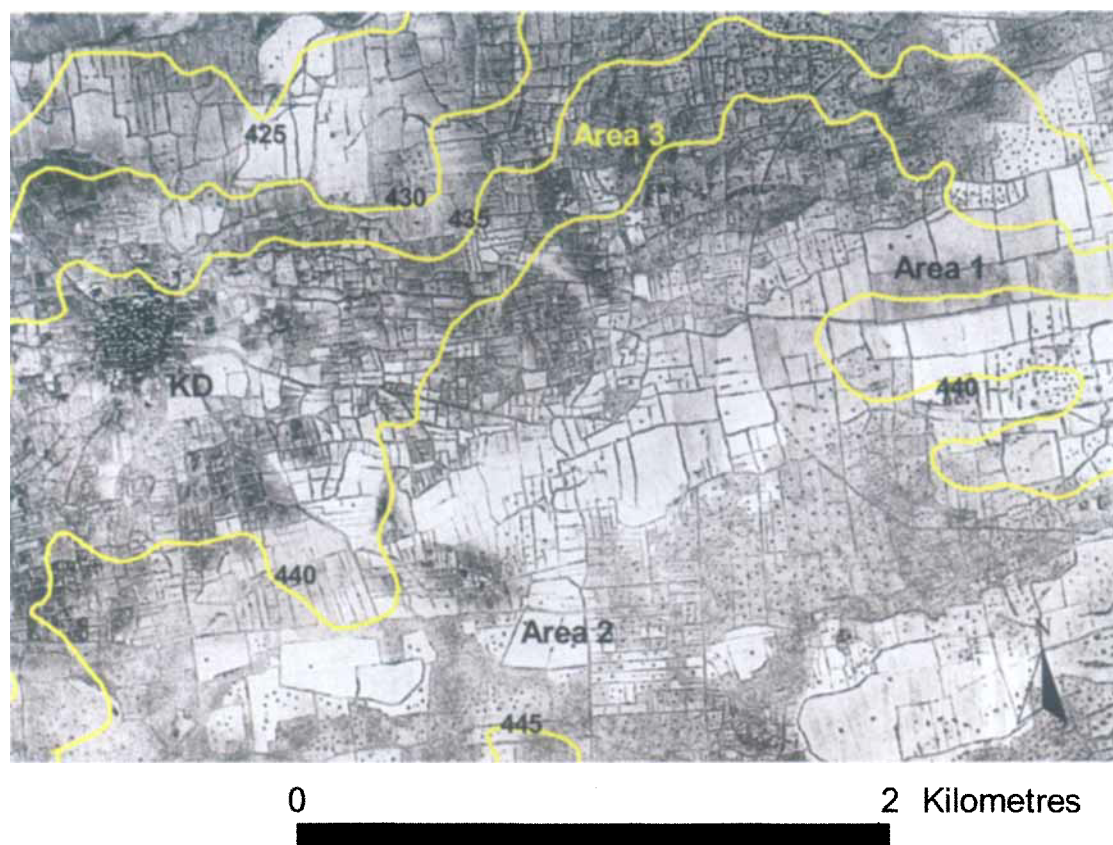


FIGURE 4. Area of basalt landscape in the northern study area, showing field systems; contours marked in yellow at 5-m intervals. Note the contrast between the large fields in Area 1, the small, regular divisions of Area 2, and the irregular field boundaries of Area 3. KD indicates the village of Karad Dehasnyeh. CORONA Mission no. 1108, 17 December 1969.

ible using CORONA. The imagery reveals considerable variability between the size and shape of fields in different areas (FIGURE 4). When contour data is overlaid, it is clear that the walls are orientated broadly east–west and north–south, regardless of local topography (FIGURE 4).

When projected at a larger-scale (FIGURE 5) the imagery permits detailed assessment of the size and layout of individual fields, and suggests the existence of major wall alignments which organize the fields into blocks. It is also possible to differentiate between stone cairns which appear as solid, dark, sub-circular features within the field systems, and ‘hollow’ ovoid features. Ground observation has revealed the latter to consist of clusters of sub-circular enclosures, presumably connected with animal

husbandry. Many examples of both cairns and enclosures are between 8 and 13 m in diameter, giving an impression of the level of detail which CORONA can provide. In this case CORONA appears to be sensitive to the different reflectance properties of the concentrations of basalt represented by walls and cairns, and the soil and vegetation matrix occurring within fields and enclosures.

Investigation of well-preserved sections of field-system indicates that these represent palimpsests, which include a variety of walls of different breadths, heights and frequently construction. A study of comparable field systems in south Syria using pre-World War II air-photographic data (Villeneuve 1985) suggested that these originated in the Roman period, although they had been much altered subse-

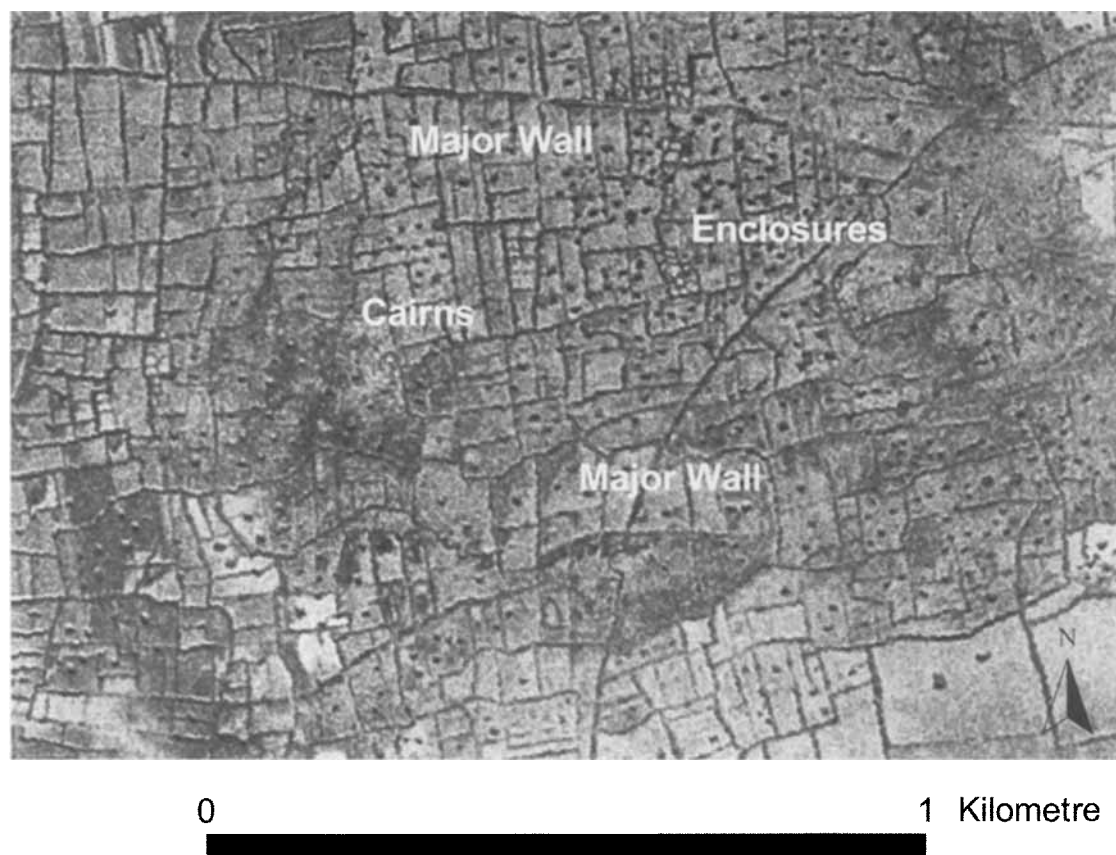


FIGURE 5. Area of basalt landscape in the northern study area, showing cairns and enclosures; some measure less than 10 m in diameter. CORONA Mission no. 1108, 17 December 1969.

quently. Equally, to judge from their structural variability, those features currently termed 'cairns' appear to fall into a number of distinct types (Philip *et al.* in press), although some are almost certainly clearance cairns as previously documented in the basalt landscape of southern Syria (Gentelle 1985: 34–5). However, these distinctions are not apparent on CORONA images.

Change detection

Dating from the 1960s, CORONA provides a key set of reference data for the analysis of landscape change. It will therefore be of use for a range of research and cultural resource management purposes. This aspect of CORONA is likely to prove of great value to local antiquities organizations in regions where rapid population growth and economic development are placing great pressure on an inadequately documented archaeological record.

Ground observation has revealed that extensive areas of the landscape described above have been destroyed in recent years by agricultural bulldozing. As a result, the field-systems as currently preserved in many areas differ significantly from those appearing in the CORONA imagery. Fieldwork in September 2000 revealed that such has been the degree of disturbance in some areas since the 1960s that it is now difficult to relate specific features observed on the imagery to the evidence on the ground. CORONA preserves evidence of the landscape as it was before recent large-scale bulldozing. The availability of an accessible, high resolution record of the landscape as it was 30 years ago, will enhance the value of newer high resolution imagery such as Ikonos (<http://www.spaceimaging.com>) for monitoring landscape change. This is because CORONA provides a critically important

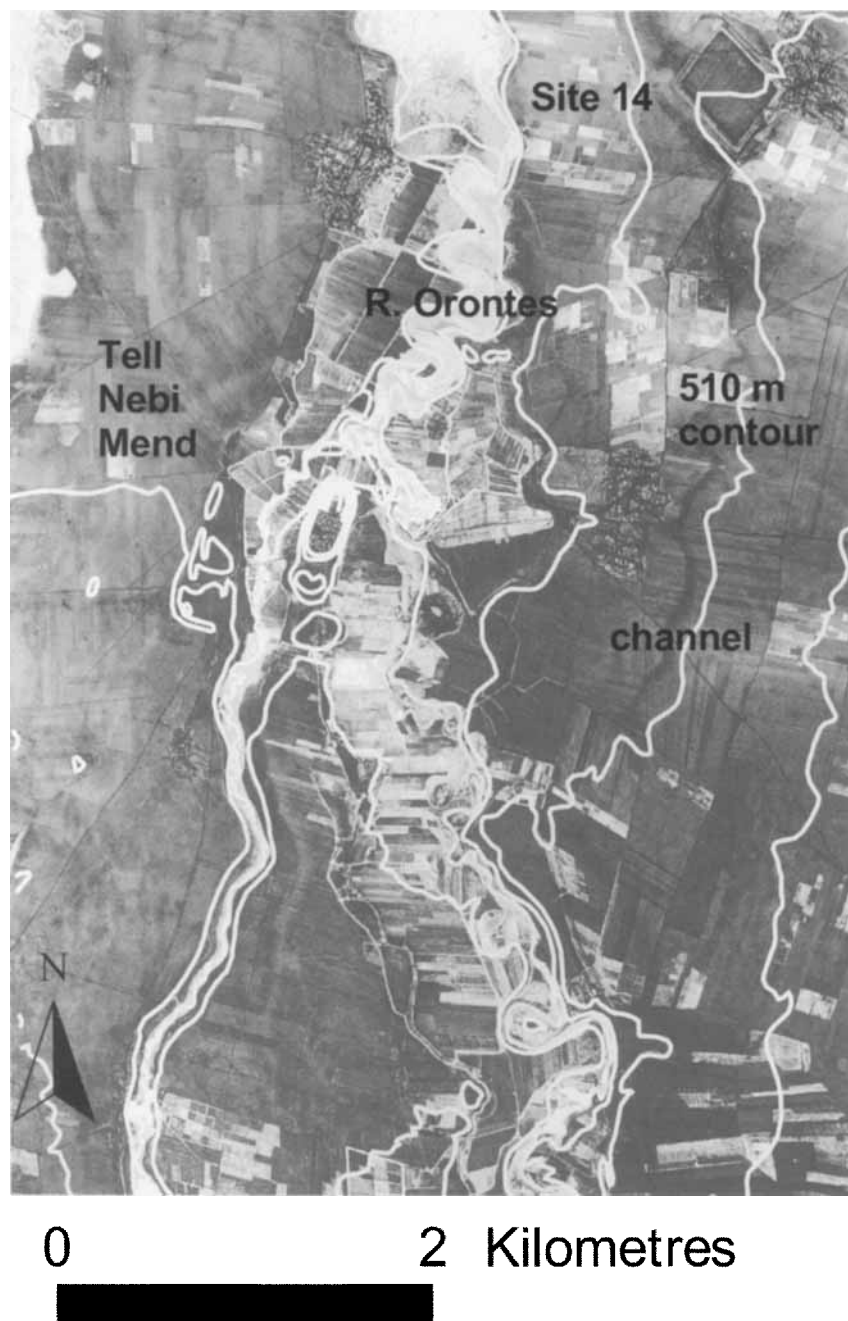


FIGURE 6. *Linear feature running east of Orontes river close to the 510-m contour. CORONA Mission no. 1111, 31 July 1970.*

high-resolution benchmark, against which subsequent landscape modification can be measured.

CORONA and landscape studies

The potential of CORONA to improve our understanding of the wider landscape is clear from

the presence on the imagery of a distinctive, sinuous, linear feature (FIGURE 6). This can be followed running in a southerly direction from the southern margin of SHR 014 (Tell es-Sefinet Nebi Noah). The latter is a large (c. 16 ha) rectangular site surrounded by an earthen rampart (light colour in the image) and external

ditch (not readily identifiable on the image, perhaps because of crop growth within it). This feature is marked on the current Syrian 1:50,000 maps as a seasonal watercourse, although it is absent from the French mandate maps produced in the 1930s.

As seen on CORONA, however, this feature differs from other seasonal watercourses in the area. These take the form of ill-defined, dark meandering features (see FIGURE 3, e.g. the wadi running northwards from SHR 256 towards SHR 472). In contrast, the feature in question appears as a clear undulating line with distinct edges. It is also short, continuing in a southerly direction from SHR 014 for some 3.5 km, before it disappears within the heavily modified agricultural landscape which predominates close to the Orontes river in this area. Secondly, while other watercourses follow descending paths that are clearly demarcated in the map contours, this feature appears to follow rather than cross the contours. The obvious implication is that it was an artificial channel, connected in some way with SHR 014.

In recent years, a major expansion of irrigated horticulture has restricted surface visibility, rendering its ground observation difficult. However in September 2001 using GPS, the team identified a clearly bounded linear feature composed of greyish silts, which is visible at several locations south of SHR 014. The observed contrast between this and the red-brown natural deposits suggests that it represents an in-filled water channel. The existence of this substantial feat of engineering has important implications for the significance of SHR 014. Above all, in the absence of good air-photographs, it is unlikely that the significance of this feature would have been appreciated without the aid of CORONA.

In this case CORONA served three key functions. It made apparent an intriguing feature that could not be identified readily, either on the ground or through lower resolution imagery. It demonstrated that the morphology of this feature was different from that of the local wadi systems, while the geocorrected CORONA im-

agery facilitated its accurate location on the ground using GPS, a vital contribution in a heavily cropped landscape.

Conclusion

The foregoing has, in our view, demonstrated not only the value of CORONA imagery in site location, but as an aid to various means of landscape assessment. The main contribution of CORONA in the southern study area appears to be its ability to aid the identification of non-tell settlement remains, in particular concentrations of occupational debris in the size range 0.5–1.5 ha, a category of site which is frequently under-represented on the maps. It might be viewed as offering a partial substitute for aerial photography in areas for which such data is not available. In the northern area, CORONA has proved an effective means of understanding the overall distribution and organization of field systems, a task which would be impossible to achieve over a significant area through ground survey alone. Finally, geocorrected Corona imagery has the potential, when linked with GPS, to allow the location of features on the ground with great speed and accuracy. While its limitations must be recognized, for many parts of the world CORONA imagery is likely to represent a significant improvement upon the information sources currently available. As such it is likely to become an invaluable tool for archaeological survey.

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